N5255

INDEX 14 LIGHTING DATA BULLETIN LD 101C

Effect of Maintenance and Color of Surroundings on Resultant Illumination

EDISON LAMP WORKS
OF GENERAL ELECTRIC COMPANY

GENERAL SALES OFFICE
HARRISON, N. J.

Where Visitors to the Institute Are Received

Model Store of the Institute

Industrial Lighting Room

At the Edison Lighting Institute, dedicated to the public for the advancement of the art and science of illumination in its many and varied applications, are portrayed most dramatically hundreds of uses of light.

Effect of Maintenance and Color of Surroundings on Resultant Illumination

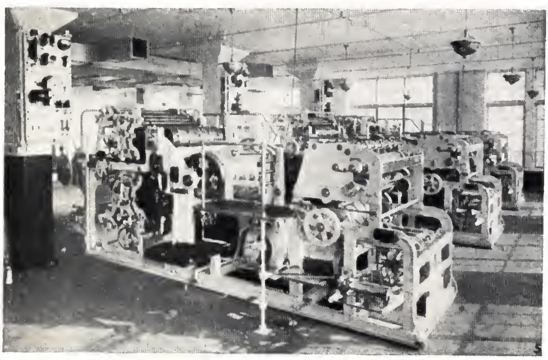
Information Compiled by
A. L. Powell *and* D. W. Prideaux
Engineering Department

In offices and drafting rooms, a light colored finish on the walls and ceiling assists greatly in obtaining good illumination upon working surfaces. Well-designed equipment provides an excellent quality of diffused light in this office, where the finish has been specified to reflect light well and give the proper distribution of brightness in the field of view. Too bright side walls are uncomfortable to the eyes.

Synopsis | Page

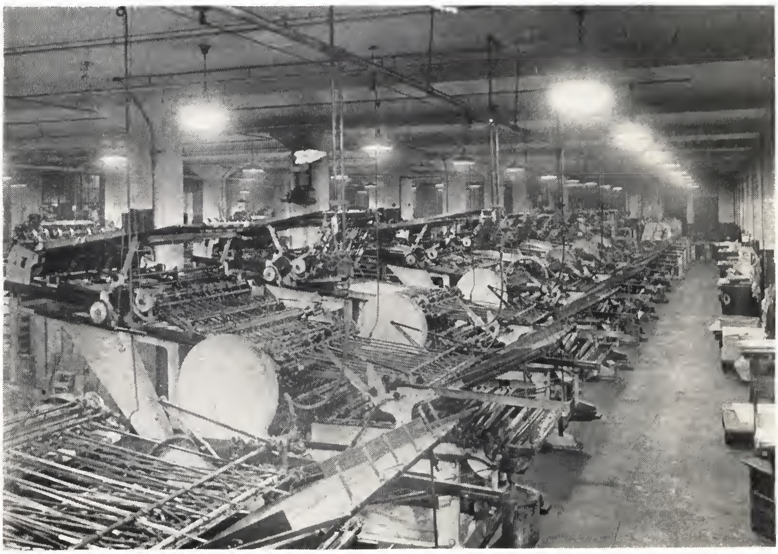
For information regarding Mazda lamps and lighting questions, refer to the nearest sales office.

To insure receipt of bulletins, notify the Department of Publicity, Edison Lamp Works of General Electric Company, Harrison, N. J., of any change of address.



Inspection of machines having a large number of parts is very materially facilitated if all surfaces are painted a light color.

But one result is possible with a combination of dark colored surroundings and lighting equipment not of the most suitable design—inadequate illumination.



The marked contrast in the illumination obtained when modern equipment is used, and reflecting surfaces, such as walls, ceiling, and machine parts, are finished in light colors, is strikingly evident upon comparing these two illustrations. The daily routine of production is carried on with much greater facility, and working conditions show immense improvement.

Effect of Maintenance and Color of Surroundings on Resultant Illumination

Information Compiled by A. L. Powell and D. W. Prideaux
Engineering Department

General Considerations

The proper maintenance of the lighting equipment is a very important factor in illumination. The housewife, for example, realizes that the home would soon become a very poor place in which to dwell unless she made periodic house cleanings and attended to the household duties in this respect from day to day. The industrial plant, or office, would soon become unsanitary unless the scrub people were employed. On the other hand, lighting equipment is often neglected from the time it is installed until it becomes obsolete. Persons seem to believe that after once hanging a fixture and screwing a lamp into a socket no further attention needs to be given to this part of the plant equipment. A widespread campaign of educating the public in this respect is most essential and it is up to everyone interested in lighting to preach the gospel of proper maintenance. The electrical contractor, when he has finished an installation of lighting, should not leave the job without advising the customer as to the necessity of cleaning. To quote a prominent social of the Department of Labor of an important industrial state, when addressing the annual convention of electrical contractors and dealers:

"If you sell a man a motor, you usually give him an instruction card telling him how to oil the motor, adjust the brushes, and the like. If you did not do this and he did not attend to the matter through his own appreciation of the subject, the motor would soon stall, burn out, and you would be justly blamed. On the other hand, many a lighting installation is sold with no instructions or suggestions as to its maintenance.

"A lighting system demands careful maintenance. If it does not receive it, the intensity will soon drop so low that the men cannot see to perform their work. You will get the blame. You will be told that the installation you designed and installed is not adequate for the purpose. Your engineering judgment will be criticised."

Many a splendid lighting installation proves unsatisfactory due to lack of attention. The best lighting installation after being in service for some time becomes unsatisfactory. A casual inspection shows dirt, dead insects, and accumulations of all sorts on the lamps and inside of the reflectors. Merely the use of a little soap and water for cleaning the equipment will bring the installation back to an entirely satisfactory condition. Lighting equipment requires as much attention as any electrical or mechanical apparatus. No plant engineer would tolerate dull tools, dirty boilers, or improperly oiled generators. Why, then, should lighting equipment be allowed to become inefficient through lack of maintenance?

In almost any office building, instances can be noticed where semi-indirect units have been allowed to go uncleaned for six months or more. Examination of the figures in Table 1 shows that approximately 40 per cent of the light is being absorbed by the dirt. A great deal of this depreciation occurs in the first few weeks, so for a period of several months the desks have been receiving only about 60 per cent of the light which was intended to reach them, and which could have been obtained at practically no extra cost if a little attention had been paid to cleanliness.

No matter how carefully designed a lighting system may be as to type and size of lamps, type and make of reflector, spacing of outlets, etc. or how well maintained, if the surroundings are not adapted to reflecting such light as strikes them, then an inefficient system will result.

The ceiling and wall surfaces in a room are secondary sources of light—receiving and reflecting light from the lamps—and merely increasing the reflection coefficient of the ceiling may greatly increase the effective illumination.

It is therefore very important to see that the ceilings are as light in color as possible. Pure white is usually to be preferred, although if a tint is artistically demanded it should be a slight cream rather than a gray or similar tone. Not only is the color of the ceiling important, but the actual finish must also be considered. A glossy surface reflects images of the lamp filament and glare is introduced, causing eye-strain. A flat or matt finish is therefore essential. A thin coating of white paint through which a dark surface may be seen has the same effect as a thin coating of enamel on a reflector. In other words, the light gets through the surface and becomes absorbed unless this surface is thick.

It is safe to say that differences between well painted white ceilings and ordinary light buff or similar colored ceilings give increase of between 20 and 30 per cent in illumination where semi-indirect or similar lighting systems are in use. This is really a conservative figure.

Depreciation of the Lighting System

There are two causes for the falling off of illumination as time passes, which might be termed acquired and inherent depreciation.

The first is by far the most serious—dust, flying particles of oil, soot and all sorts of foreign matter collect on reflector surfaces and lamp bulbs. These form a coating which, from its black and dirty nature, absorbs a high percentage of the light which must penetrate it before reaching the work.

The inherent depreciation or blackening of the lamp is on a much smaller scale. As the quality of lamps improves year by year this inherent depreciation lessens in magnitude, though it always should be taken into consideration.

Acquired Depreciation

Many factors affect the rate of depreciation of the lighting installation as a whole.

(a) LOCATION—An installation in a suburban office will have a much lower rate of depreciation than one downtown in a soft coal burning city; the units in a machine shop with flying oil particles naturally get much dirtier than those in a store. Between extreme conditions the difference in rate may easily be as great as 8 to 1.

(b) TYPE OF UNIT—Obviously, a steel, direct lighting-reflector will not depreciate as rapidly as an indirect unit. In the case of the former the under surface of the reflector offers very little opportunity for dust to gather, and that on the lamp bulb will be the primary cause of loss. In the case of the inverted unit, however, a thin layer of dust soon settles on the entire reflecting surface, as well as on the lamp, which will reduce the light output appreciably in a very short time. Not only is this true, but the very arrangement of parts makes the accumulation greater. With the direct lighting equipment, the reflector itself shields the lamp from falling particles, whereas they enter directly into the inverted unit.

(c) DESIGN OF EQUIPMENT—While in general there is a marked difference between types, there may also be considerable variation with the same type, depending on the details of construction.

For example, opalescent enclosing globes with bottom holes or vents have nearly twice the depreciation of those without this hole. The current of heated air carries dust particles which are deposited on the interior of the globe. Similarly a globe having sharply sloping sides will tend to accumulate less dirt than one of a flat character. The roughness or smoothness of the exposed surface will affect the rate of depreciation. The proportion of direct light coming from the unit will be a factor in the situation. Opal bowl reflectors serve as an illustration of this point. With a light density unit, more light is transmitted through the glassware, and dirt on the outer surface will have appreciably more effect than on a denser reflector.

TABLE 1

Approximate depreciation expressed in percentage of initial illumination on the working plane
(Estimated from test records)

TYPE OF UNIT	4 WKS.	8 WKS.	12 WKS.	16 WKS.	20 WKS.
R.L.M. Standard Dome	4	8	10	12	14
Glassteel Diffusers	6	9	11	13	15
Opalescent enclosing globes (no vent)	7	10	12	14	16
Translucent direct lighting bowl reflectors	10	14	17	20	22
Semi-indirect	14	23	32	36	40
Total indirect	18	33	41	48	50

It is most difficult to present in a single table a comprehensive picture of the rate of depreciation of different types of equipment. The above figure should not be taken too literally. They represent what might be expected of standard styles of luminaires under average office conditions of an industrial city.

As pointed out later, the question of color of walls and ceilings is very important. No matter how carefully painted a room may be, soot, smoke, and other agencies soon darken the surfaces of the room and cause it to lose a considerable amount of its reflecting power. Any porous paint, such as calcimine or whitewash, is particularly susceptible to this effect. A test, to determine the reflection coefficient of the ceiling and walls at frequent intervals, may enable a considerable saving on the lighting bill. In general, paint is far cheaper than electrical energy, and in dirty plants, painting or cleaning is especially important.

Inherent Depreciation

As the MAZDA lamp is burned, small particles of tungsten are evaporated from the filament and collect on the lamp bulb in the form of a dark deposit. With the MAZDA C lamp the gas current carries these particles to the upper part of the bulb, where they have less effect in absorbing light than when deposited directly opposite the filament. Nevertheless, any accumulation on the interior surface of the bulb absorbs light, and blackened lamps should, of course, be replaced.

From an economic standpoint, taking into consideration price of lamp and cost of power, a lamp should be discarded when the bulb has become noticeably discolored (candlepower 75 per cent or less of initial). Of course, a photometric test might be desirable to determine exactly the percentage of depreciation, but observation and experience will soon indicate to the maintenance department when the lamp should be removed. Photometric test will show that when the bulb opposite the filament is noticeably blackened there has been a marked falling off in candlepower and that lamps of this character should be replaced. MAZDA lamps are so designed that when operated under proper conditions they should give an average life of one thousand hours before it should be necessary to remove any lamps due to blackening. However, it is impossible to predict what an individual lamp will do and occasionally it may be desirable to remove a lamp on account of blackening before it reaches a life of one thousand hours.

The matter of operating lamps at correct voltage warrants very serious consideration, and observation indicates that in general conditions in service leave much to be desired. The uninitiated is inclined to believe that if the wiring in the building meets the Underwriters' requirements that it is satisfactory from an operating standpoint. This is far from the case, for the Underwriters' requirements as to wire sizes are only to prevent dangerous heating of the conductors, and have nothing to do with the supplying of proper voltage at the socket to insure full candlepower from the lamps, or with the avoidable waste of kilowatt-hours which may take place in the wires. Adequate wiring should always be installed and this implies but a small voltage drop.

It is good economy to spend a little more on the wiring system and avoid future losses. For example, calculations indicate that a given building might be wired at a cost of $7970 and meet the

Underwriters' requirements for the contemplated load. Adequate wiring in this building would have cost $9500. With wiring of minimum capacity to meet code requirements, the annual loss of energy due to inadequate cross-sectional area, which would have been dissipated in heating the wires, would have been increased nearly $400 per year, assuming ordinary operating conditions and current costs. It is evident that this would eat up the entire saving in investment within the first four years; also during this time with the cheaper wiring the lamps would be operating at approximately ten per cent under their rated candlepower.

Wire sizes for all classes of lighting installations should be such that the voltage drop between the panel box and the outlets does not exceed two volts. The following table shows the wire size required for various conditions in order to fulfill this requirement.

TABLE 2

LENGTH OF RUN (PANEL BOX TO OUTLET)	WATTS PER CIRCUIT						
Feet	800 to 1000	1000 to 1200	1200 to 1500	1500 to 1800	1800 to 2200	2200 to 2600	2600 to 3000
30 or less	14	14	14	12	12	10	10
30 to 45	14	12	12	10	10	10	8
45 to 60	12	12	12	10	8	8	8
60 to 80	12	10	10	8	8	6	6
80 to 100	10	10	8	8	6		
100 to 120	10	8	8	6			
120 to 150	8	8	6				
150 to 200	8	6					

Another feature in plant operation which has come to our attention is the use of larger lamps as time passes and the need is felt for more light. These are sometimes fitted with the proper size of reflectors, but are too frequently substituted in reflectors designed for smaller lamps. This practice, of course, produces serious glare and gives a poor distribution of light. Very rarely is any thought given to rewiring for this increased load—which is sometimes twice that originally installed. The wiring, generally, is not of sufficient capacity to carry the new load without an excessive voltage drop. The plant engineer should investigate every case of increased loading of circuits and make a check of the size of feeders and branch circuits if he desires to obtain the full efficiency of his lighting system.

Cleaning—*Costs and Frequency*

All lamps and reflectors should be regularly washed and cleaned. The period between cleanings will vary with locality and type of equipment. With direct lighting equipment, the dirt gathers on the exterior surface and is readily visible to the occupants of the room. With the semi-indirect and totally indirect systems, the dirt gathers on the inner or reflecting surfaces and is not noticed until conditions become so aggravated that the illumination drops far below that intensity for which it was designed. Hence, a careful maintenance of any indirect system is extremely important.

Haphazard cleaning has not usually been found effective, since the accumulation is so gradual that it is not readily noticed by those responsible. Much better success has been secured by organized cleaning, at stated intervals, under the charge of a maintenance department where one person is absolutely responsible. Considering average conditions and typical equipment, the fixtures in an office should be wiped off at least once every month, and removed for careful washing once every three or four months. In the foundry it is probably necessary to clean fixtures carefully once a week, the conditions under which adequate lighting must be obtained in this industry representing perhaps one of the most difficult situations ordinarily encountered.

As giving an indication of the actual time required for cleaning, a case is on record of a large office building which employs a competent man under the direction of the chief janitor to carry on the work of cleaning and relamping fixtures. This man devotes his entire time to maintenance. Each unit is cleaned thoroughly every four weeks. There is a total of about twenty-five hundred indirect fixtures in the installation and he is able to clean approximately one hundred per day.

As typical figures, for industrial plants with direct lighting reflectors, from three to five cents for cleaning might be considered as average costs. Some figures obtained in a large office building, where semi-indirect units of a fairly simple design are in use, indicate that the cost of cleaning by wiping lamps and reflectors with a damp cloth and the drying is approximately five cents per unit. Removing the semi-indirect bowl from the fixture and carefully washing, costs approximately ten cents. The most economic period for cleaning a given installation can be obtained by taking into consideration the cost of power, the burning hours per day, the loss of light due to the accumulation of dirt, and the cost per cleaning.

Method of Cleaning

At first thought it would appear that for dry dust, wiping with a cloth or brush, would be adequate, but tests have indicated that such a method only removes about half the foreign material that a wet or damp cloth does. It must be borne in mind to dry all surfaces thoroughly for a satisfactory job. Greasy or wet accumulations on any type of reflector must be removed by washing. Soap and water are good agents, but care must be taken to remove the film of soap by rinsing thoroughly as dried soap accumulates dust very rapidly. There are a number of cleaners on the market, but before these are used on a polished surface care should be taken to see that they are smooth so as not to make microscopic scratches on the glass, and do not leave a film of cleaning material. Most of these may be applied with a piece of cotton waste or soft cloth, and polished off with dry waste or cloth. Where lamps are hung high, and it is necessary to use a ladder to reach them, it is advisable to have on hand an extra globe or reflector which may be put in place of the dirty globe, and the latter carried to the cleaning place. After washing, the clean globe can be substituted for the next dirty one, and so on. This procedure necessitates only one trip up the ladder for each globe or reflector.

In some industrial plants, such as foundries, it is necessary to locate the units at a considerable distance above the floor. Because of the moving crane and the excessive height it is oftentimes very hard to reach these lighting units to clean them. Usually in this type of concern the air is charged with dust particles and steam, which makes the depreciation of the lighting unit extremely large. For such locations disconnecting hangers as shown have been developed, which allow the units to be easily lowered to the floor for thorough cleaning and relamping. In most places operating the hanger once a month should be sufficient to keep it in good working condition. When a lamp is not lowered for a year or more, as has happened, it might be reasonable to expect that under some conditions much dirt and corrosion could accumulate on the apparatus and prevent it from working. Provision is made, however, for easy inspection and cleaning, as all moving parts are usually on the lower member and therefore come down with the lamp.

Since the question of proper maintenance is such a vital factor in good lighting practice, it is most desirable to examine with care

the fixture one is planning to install, from this standpoint. Is it of a shape that will tend to collect dirt? Are there deep crevices which will be difficult to clean? Are the surfaces roughened and hence dust-catchers requiring scrubbing to be made clean? Are there many parts to remove in order to clean the glassware properly and replace the lamps? Do these parts fit easily or are they held in place by small screws, clips, or other devices requiring considerable "juggling?" Are the parts clumsy or awkward to handle, increasing the likelihood of breakage? A careful analysis along these lines will prevent much annoyance after the installation is made and make it possible to have good lighting at all times with minimum effort.

Certainly no progressive business manager can afford to be without a means of checking the illumination he is providing his workers. A reading at stated intervals will tell him whether the porters are tending to their duties of cleaning lamps and reflectors. He does not need to climb a ladder and look into the lighting fixture when he believes dirt has been collected. He merely takes the FOOT-CANDLE METER out of his desk and, knowing what the standard should be, checks the "light on the work."

The foot-candle meter—a practical aid for promoting good lighting

This small portable photometer will be of practical use in any type of business or manufacturing establishment. This enables one to read at a glance the illumination on the desk, counter, workbench, or table, It is most simple in operation and very compact. By its use the lighting of existing installations may be checked to determine whether the illumination conforms to modern standards.

When employees complain that they are not receiving proper illumination, this little instrument forms an excellent arbitrator. Tables showing the desirable intensities of illumination for different kinds of work are to be found in most publications on lighting and the actual illumination can be readily compared with these values. If too low, the necessary corrections can be made, or if as good or better than the standard, the dispute is settled at once.

Table 3

Influence of Reflection Factor on Illumination Obtained Under Various Conditions

Relative Foot Candles

Room Size	Reflection Factor of Walls Per Cent	Reflection Factor of Ceiling														
		R.L.M. Reflectors					Enclosing Globes					Indirect Fixtures				
		70%	60%	50%	40%	30%	70%	60%	50%	40%	30%	70%	60%	50%	40%	30%
Large Room, at least 60 x 60 feet with 14-foot ceiling	50	100	98.5	96.5	94.5		93	87.5	82.5	78		70	59	49	40	
	40	98	96.5	94.5	92.5		89	84	79	75		68	57	47	38	
	30	96.5	94.5	93	91	89.5	85	80	75.5	71	66.5	65	55	45.5	36	26.5
	20	94.5	93	91	89.5	88.5	81	77	73	69	65	62.5	51	44	34.5	25.5
	10	93	91	89.5	88.5	87.5	77	73.5	70	66.5	63	59.5	46	42	31.5	24.5
Medium Size Room, 20 x 50 feet with 12-foot ceiling	50	86	85	84	83		74	70.5	67	63.5		52.5	45.5	38.5	31.5	
	40	83	82	81.5	80		70	66.5	63	60		50	43	36	29	
	30	80.5	79.5	79	78	77	67	63.5	59.5	56.5	54	47.5	40	33	26	19
	20	78	77.5	77	76	75.5	62	59	57	54	51.5	45.5	38	30.5	24	18
	10	75.5	75.5	75.5	74.5	74	58	56	54	51.5	49	44	36.5	29	23.5	17.5
Small Room, 15 x 15 feet with 10-foot ceiling	50	68.5	67.5	66.5	65.5		54.5	52	49	46		38.5	32	26.5		
	40	67.5	65	64	62.5		50	47	45.5	43		36	30	24.5		
	30	63	62	61.5	60	59.5	45.5	43	42	40	38.5	33.5	28	23	18.5	14
	20	60.5	60	60	59	58	43.5	41.5	39.5	37	36	30.5	26	21	17	13
	10	58	58	57.5	57	56.1	40.5	38.5	37	35	33.5	28	23	19	15	12

Reflection Factors for Light from Mazda Lamps

Ceiling Tints

White Flat 82%

White Egg Shell 81%

White Gloss 84%

Ivory White 79%

Cream 74%

Silver Gray 75%

Side Wall Tints

Ivory Tan 67%

Buff 55%

Side Wall Tints (*Cont.*)

Tan 48%

Light Gray 59%

French Gray 32%

Light Green 62%

Medium Green 49%

Light Blue 52%

Medium Blue 43%

Pink 72%

NOTE — The division between ceiling and side wall finishes is by no means absolute, many of these designated as ceiling tints being used as wall finishes. The indicated range is, however, desirable from a lighting standpoint.

Reflection Factors for Light from Mazda Lamps

Dado Paints

Gray Gloss
22%

Olive Green Gloss
13%

Dark Brown Gloss
9%

Natural Finishes

Natural Brick
13%

Cement
24%

Wood Finishes

Light Oak
34%

Dark Oak
13%

Walnut
7%

Wood Finishes (*Cont.*)

Mahogany
8%

Wall-Papers

48%

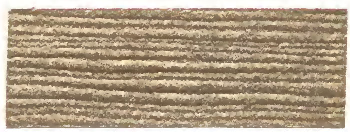
42%

46%

40%

35%

38%



25%

Economics of Proper Painting

It is true that it is appreciably more expensive to paint an interior correctly than to apply calcimine or some other paint which depreciates rapidly or has initially low reflecting power, but careful analysis reveals that the expenditure is well warranted.

The effect of reflection factor upon resultant illumination is very great indeed. If all surfaces of the room were black with no reflecting power, the illumination on any surface would be only that received direct from the lamps. If all surfaces had a reflecting power of 50 per cent, the illumination would be practically doubled. If the reflection factor of surroundings were in the order of 90 per cent, the illumination would be increased nearly ten times.

As a practical case one might consider a room where the ceiling is painted with a poor type of oil paint which depreciates quickly, or a water paint which usually loses its reflecting power very rapidly; lighted by semi-indirect luminaires. It is safe to assume that at the end of two years the illumination will have decreased not less than 20 per cent due to the reduction in reflecting power of the ceiling, other conditions being constant. But actually, other conditions are not constant. The reflecting power of the walls will also undergo a loss and it is probably safe to assume that the use of poor paint alone results in a progressive loss of light amounting to at least 15 per cent of that measured at the beginning of the year. Thus a room so painted of 400 sq. ft. floor area initially lighted by four 150-watt lamps, would require an additional 150-watt lamp at the end of two years to bring the illumination back to what it was at the beginning —an increase of 25 per cent in energy consumed and lamp costs. Surely this figure is striking enough to warrant the initial expenditure for proper painting.

The extent of the influence which the color of the walls has upon the illumination available upon the working plane may be realized by reference to Table 3, in which interesting comparisons of the foot-candle levels obtainable with the same lighting units, but under different conditions of reflecting surfaces, are presented.

Reflecting Properties of White Paints

A considerable number of tests and investigations have proven that a pure white is generally most suitable for the ceiling in order to reflect as much of the light flux as possible downward. All things considered, white paint is probably of the greatest interest in

connection with illumination, and nearly two years ago a series of tests were undertaken to determine, first, the kind of white paint having the highest initial reflecting power when applied to various surfaces and, second, to determine the rate of depreciation of the various paints under different conditions.

Within the last decade there has been a marked improvement in the reflecting properties of commercial white paints. This is due to a realization on the part of the paint manufacturers of the importance of the matter and applied research on their part. Ten years ago the average reflection factor of industrial white paints when new was less than 70 per cent, now (as shown more in detail later), the average is over 80 per cent.

In general, paints may be divided into two varieties, oil paint and water paint—depending upon the liquid which is used as a vehicle for the pigment. Oil paints, of course, although more expensive, are much more durable than water paints, can be cleaned, and act as preserving coats for the surfaces to which they are applied. Many previous tests have shown the rapid depreciation of water paints and have established this fact so well that a consideration of their qualities is not necessary here. Water paints should only be used as a temporary measure.

In the test mentioned above, 26 samples of various compositions were applied to wood, concrete, and metal surfaces. Two specimens were prepared with each sample on each of the surfaces. One set of these was sealed up in a dust-proof cabinet with a glass front. This was placed in such a position as to receive direct north skylight. The test on this set of samples would show what might be termed the inherent depreciation of the paint or that due to the action of light alone.

The second set of samples was placed close to the ceiling in a factory building where there was a certain amount of very small metallic and graphitic particles in suspension, and a fairly high percentage of products of combustion. This test would show the acquired depreciation which a paint would have under conditions probably slightly more severe than normal industrial service.

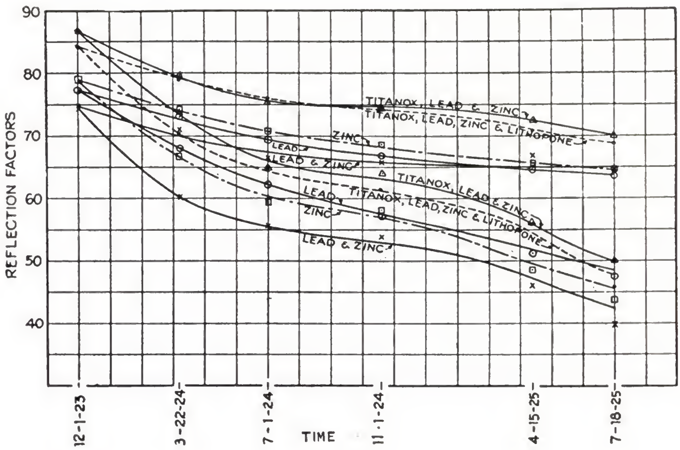
The initial measurement of reflection factor of the 26 types of white paint tested showed an average value of 81.1 per cent. The maximum value found was 87.6 per cent which is for a flat paint with titanox lead and free zinc as pigment material. The minimum value was 75.5 per cent for a flat paint with lithopone as the pigment material.

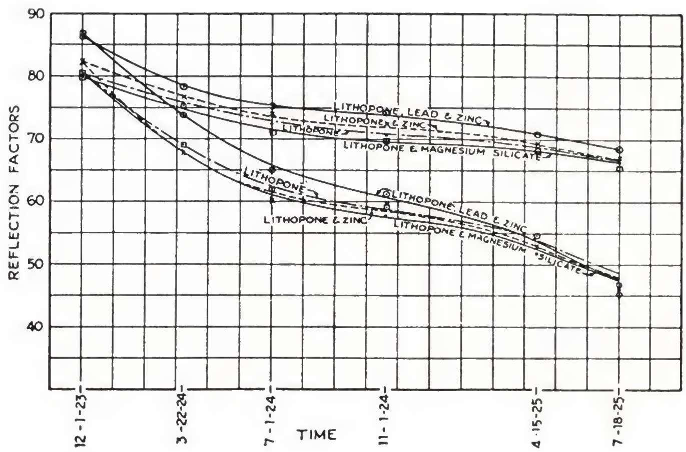
TABLE 4

Specimen No.	Basic Pigment	Type of Finish	Initial Reflection Factor	Average Reflection Factor During 20 Months		Appearance at End of Test
				Cabinet Set	Factory Set	
1	Lth & Zn O	Undercoat Semi-Gloss	81.9	73.1	64.7	Grayish
2	Zn O & Lth	Eggshell	82.5	71.3	62.0	White
3	Titanox Pb & Zn	Flat White	86.9	76.3	65.7	White
4	Lth Pb & Zn	Gloss	86.6	75.3	63.5	Bluish
5	Lth Titanox Pb & Zn	Eggshell	84.3	75.3	63.2	White
6	Zn O & Lth	Flat White	85.2	76.4	64.3	White
7	ZN O & Lth	Gloss	83.7	74.8	57.6	Bluish
10	Lth	Enamel	80.4	73.75	57.9	White
11	Lth	Flat White	82.7	75.9	61.8	Cream
12	Lth & Zn O	Gloss	81.8	74.5	59.15	White
13	Lth	Eggshell	81.7	74.4	61.8	Cream
15	Lth	Flat White	81.7	74.8	69.9	White
16	Lth & Zn O	Gloss	82.2	74.8	61.1	White
17	Lth	Semi-Gloss	78.5	72.8	60.6	Cream
18	Zn O	Semi-Gloss	75.8	68.8	57.2	White
20	Lth	Flat White	76.3	68.0	59.2	White
21	Lth	Eggshell	79.75	69.4	58.3	White
22	Lth	Gloss	77.4	68.7	52.9	Cream
24	White Pb	Flat White	77.25	68.5	59.8	White
27	Zn O	Enamel	83.5	65.8	59.65	White
29	Pb & Zn O	Eggshell	75.1	68.3	55.5	Cream
30	Lth & Mag's'm Silicate	Eggshell	80.0	70.7	60.7	White
32	Lth & Zn O	Gloss	80.1	73.8	61.5	White
33	Lth & Mag's'm Silicate	Flat White	80.0	72.5	62.2	White
34	Lth	Eggshell	81.4	73.5	61.7	White
35	Lth	Gloss	82.1	73.6	63.2	Grayish

The tests indicated that the character of the material to which the paint is applied has practically no effect on the rate of depreciation, and further, that the type of finish (gloss, eggshell, or flat) had, on the average, little effect on the rate of depreciation.

The curves shown on page 18 are obtained by grouping specimens of the same basic pigment together and averaging values regardless of the character of finish. Study of these average curves alone would indicate that the paint having titanox as a part of the pigment had the highest initial reflection factor; those of a lithopone component next in order; while the lead and zinc paints fall below the other types. The rate of depreciation of the different groups is in this order also. These average curves, however, do not





Average depreciation curves of paints of various components as indicated, applied to wood, concrete and metal surfaces. In each instance the upper set of curves shows the rate of depreciation of samples enclosed in a glass cabinet exposed to the light but protected from dust. The lower set of curves shows a depreciation of samples placed close to the ceiling in a factory building.

tell the whole story, for there may not be enough varieties of certain types to give good average figures, whereas with other types there may be instances of high values grouped with exceptionally low values.

The question naturally arises as to what is the best type of paint for different conditions, and one must stop to analyze what

is required of the paint. The initial reflection factor certainly does not tell the whole story. One paint may have a very high initial value and its rate of depreciation may be quite rapid; another may have a lower initial reflection factor and yet over a period of time actually reflect more light—in other words, depreciate at a lower rate. It is the area under the curve which tells the story. The two sets of curves, similar to those shown, but for individual specimens, have therefore, been integrated and their average reflection factors for the period of twenty months are set forth in Table 4.

Another interesting point is the change in tint of the paint over a period of time. Initially all specimens would have been classified by the average individual as practically pure white in color. Some change their appearance as indicated in the table.

A third point to consider is the location where the paint is used. If very dirty, the specimens which show up best in the factory test are likely to be most useful; if quite clean, those which give the highest value in the cabinet group would be the logical choice.

In general it may be said that for a paint to be permanent it must be composed of chemically inert substances of high refractive index, ground exceedingly fine (to produce density), and mixed with an inert vehicle. The vehicle is a very important factor and the indications are that linseed oil, though frequently used in the past, is not very satisfactory for this purpose.

Coefficient of Reflection of Colored Paints

It is rather difficult to tabulate the reflection factors for various colors. A number of elements create this condition. There is no standard terminology of paint colors. A tint which one manufacturer may call ivory-tan may be quite different in appearance and reflecting properties from some other maker's color under the same name. The chemical composition or method of mixing the paint will have an effect on its ability to reflect light. A higher or lower oil content, for example, produces some variation.

The most feasible means of presenting the necessary data seems to be to tabulate a number of commonly used colors under a rather broad classification and give a range in percentage for any particular color. This is supplemented with several typical finishes in the form of chips with the coefficients of reflection for the specimen shown. Quick drying lacquers and the enamels of today present possibilities of refinishing furniture or rooms with the least loss

of time. The wall or ceiling finish under consideration can be compared with these samples and the reflection factor estimated with a fair degree of accuracy by evaluating the figures given for the color which most nearly matches. A few examples of wall papers are presented which indicate the tendency. Wall papers exist in such extremely wide variety that it is impossible to cover the question in detail. Natural wood finishes are of the order indicated by the four samples shown.

The figures presented in the following table are the results of a considerable number of tests by different authorities and indicate the wide range of color which is often classified under one name.

Color	Percentage of Light Reflected
White—new	82 to 89%
White—old	75 to 85%
Cream	62 to 80%
Buff	49 to 66%
Ivory	73 to 78%
Gray	17 to 63%
Light green	48 to 75%
Dark green	11 to 25%
Light blue	34 to 61%
Pink	36 to 72%
Dark red	13 to 30%
Yellow	61 to 75%
Dark tan	30 to 46%
Natural wood brown stain	17 to 29%
Light wood varnish	42 to 49%

Measurement of Reflection Factor

To accurately determine the reflection factor of a surface it is necessary to employ some device which insures the elimination of errors introduced by varying direction of light, specular reflection, etc. A simple form of apparatus which makes possible reliable results is described in detail in one of the references in the bibliography.* This employs some form of sphere, a small photometer, and a projection lantern.

The sight tube of the photometer is first directed upon the walls of the sphere and a reading of apparent foot-candles is made. This is considered as the illumination incident upon the sample. The photometer is then directed toward the sample and a second reading is taken. This is considered as the light reflected from the sample. The ratio of these two figures is the reflection factor. Inasmuch as completely diffuse illumination is used in both cases the elements of specular reflection, direction of incident light, etc., are eliminated.

* Sharp & Little—"Measurement of Reflection Factors."

As a standard for any reflection factor measurements a freshly scraped block of pure magnesium carbonate should be used. One of these can be secured at any drug store. A block approximately four inches square by two inches thick can be purchased for a few cents. Its coefficient of reflection has been determined many times and through cross checking has been standardized at 98 per cent.

The practical determination of the coefficient of reflection of a diffuse reflecting wall or ceiling is quite simple indeed and can be made by anyone familiar with the operation of a portable photometer employing a detached test plate. The first step in the deter-

In determining the coefficient of reflection of a wall surface with the Macbeth Portable Photometer, the secondary standard, previously calibrated, is affixed to the wall, and a reading taken of the normal illumination incident to the paper surface. After this the paper is removed and a reading taken of the wall surface itself. As explained in the following text, the coefficient may then be readily calculated.

mination is to scrape the surface of a magnesium carbonate block and place it in any convenient position relative to an artificial light source. The photometer is then pointed at the block from some angle not too far from the normal and a reading taken and recorded. A secondary standard or working standard such as a sheet of blotting paper is next calibrated. This is substituted for the magnesium block, and with the same illumination incident on it as when the previous reading was taken a second reading is taken and recorded. We then have the following proportion applying: Reading "A" is to 98 per cent as reading "B" is to the coefficient of reflection of the blotting paper.

Taking care that the blotting paper or secondary standard does not become dirty, it is removed to the room in which the test is

desired, placed at a convenient position on the wall or ceiling the reflection factor of which is desired, and with the portable photometer a reading taken of the brightness of the blotting paper with the normal illumination received on the wall incident on the paper. The paper is now removed and a reading taken of the wall surface. We have already determined the coefficient of reflection of the blotting paper and the following proportion applies: "Reading" on blotting paper is to the "Coefficient of Reflection" of blotting paper as "Reading" on wall is to the "Coefficient of Reflection" of wall.

If the surface to be tested is polished or has a considerable element of specular reflection, then the determination of the coefficient is more complex, and several readings at different angles should be taken to insure the obtaining of a fair average value.

No difficult mathematical equations are involved in this determination. Simple readings of the photometer and a proportion are all that are necessary.

EXAMPLE:

Calibration

Magnesium Carbonate Block—Apparent Foot-candles, 10.5
White Blotting Paper—Apparent Foot-candles, 9.1
10.5 is to 0.98 as 9.1 is to X
Coefficient of Reflection of Blotting Paper (X), 85 per cent

Test of Wall Surface

White Blotting Paper in Place—Apparent Foot-candles, 3.7
White Blotting Paper Removed—Apparent Foot-candles, 2.6
3.7 is to 0.85 as 2.6 is to X
Coefficient of Reflection of Wall (X), 60 per cent

Method of Applying Paint

As pointed out, gloss enamel is usually objectionable from a lighting standpoint, having the property of producing specular or image reflections of the lamps. Flat or eggshell enamel finishes overcome this, and, in spite of the popular concept to the contrary, are not appreciably more difficult to clean. Furthermore, tests indicate that the inherent as well as the acquired depreciation of flat finishes as a class is not greater than that of the gloss. Hence there is every reason for using a flat finish as a final coat when painting interiors.

In painting any sort of surface, it is necessary that it be thoroughly covered with pigment both for protection and light reflecting properties. The under coats can well be of a less expensive though

opaque variety. All coats must, however, be chemically inert and non-porous when dry.

As the ceiling of the room is most important from the standpoint of light reflection, special attention must be paid to its treatment. It is recommended that a plaster ceiling be treated as follows:

First coat—good impervious primer
Second and third coats—high grade lithopone paint (not less than 75% lithopone)
Fourth coat—high grade eggshell enamel

Among the typical high grade paints for the last coat, the following have been found by extensive test to be satisfactory from the standpoint of initial reflection factor, as well as low rate of depreciation.

Savakota—Chas. M. Childs & Co.
Tecmilite—Dean and Barry Co.
S. W. Eggshell Mill White—Sherwin-Williams Co.
Moore's Mill White—Benjamin Moore Co.
B.P.S. Inside White—Patterson-Sargent Co.
Rice's Mill White—U.S. Gutta Percha Co.
Degraco—Detroit Graphite Co.

For metal ceilings, after scale removal, the first coat should be of red lead mixed with raw linseed oil dryer and turps. The second coat should be a high grade lithopone paint finishing with an oil gloss, and then the third coat high grade eggshell enamel.

From an illumination standpoint the walls of a room are not as important as the ceiling and a less expensive method of painting will serve. First coat—good impervious primer mixed with an equal part zinc lithopone paint. Second and third coats—high grade zinc lithopone paint of which the last should be tinted to the desired color.

Desirable Finishes for

(a) Industrial Plants

As a result of a campaign of education on the part of certain paint manufacturers, the industries now realize that natural light is greatly aided if the interior surfaces are light in color. Any light striking these parts of the room is reflected in a degree depending upon the color. If the surface is dark brown or smoke coverd possibly only 10 per cent of the light will be reflected. If the surface is pure white the reflection coefficient may be as high as 80 per cent.

With light colored surroundings the maximum light is made available and surprisingly high utilization constants can be obtained in rooms properly painted. Cases have been noted where this constant has been over 1.00. With a white ceiling and side walls, and light wood floors, before the machinery is installed, the cross reflections are so numerous that this result is obtained. The photometer actually measures the same energy more than once. Figures of this order cannot be expected in practice but serve to illustrate how important the color of surroundings is in enabling one to have the maximum amount of light on the work for a given expenditure for current.

The lower part of the sidewalls is of less importance in reflecting light, and for purposes of appearance it is often desirable to have a dado of dark green or some neutral color, as fingermarks and other disfigurements are not so noticeable. This treatment of the walls also reduces the brightness of the background in the field of view.

High grade oil painting is most desirable, but where whitewash is absolutely necessary, frequent cleanings will speed production and keep the lighting bills at a minimum. A clean, bright shop has a decided effect in improving the morale of the workmen.

The painting of the machines themselves in the factory can well receive attention. That a coat of paint will materially lengthen the life of a piece of apparatus is well understood. If this paint is of a suitable character it will serve an additional purpose in assisting the lighting. Such a paint should be hard in order that it may not be easily marred; smooth, yet not glossy, in order that it may be easily cleaned, collect the minimum dirt, and not give annoying reflections; light in color in order that it may function as mentioned above. It should of course resist the action of oil and cutting tool composites.

Various colors are suitable for this painting of machinery. White or cream is not generally applicable for it shows stains too readily. Light gray and light orange have been used with success. They reflect about 35 per cent of the incident light and find many applications about the industrial plant. A few of these are indicated in the illustrations. With complicated machinery, such as a printing press, lighting is difficult, but with the surfaces properly treated to reflect and diffuse the light, gears and the undersides of rolls are clearly visible, and can be readily adjusted, and safe operation becomes possible. A bright, light shop is a cheerful and

pleasant place in which to work and there is a natural tendency to keep light colored objects clean, thus promoting sanitation.

Proper painting of machinery will also make safe operation possible; the shadows which prevail around the punch press, slotter, and stamping mill are eliminated, and moving parts made visible.

(b) Offices, Schools, and Stores

On account of the justly widespread use of the indirect lighting systems and the likelihood of these being installed at any time, the ceilings should always be light in color.

For the walls, a soft pale olive green with a slight blue cast is recommended in north rooms and with a yellow cast in south rooms to give the best results. The matter of tint of the wall surfaces, however, is largely a matter of personal preference. Some individuals prefer a greenish tint which is soft and restful, others for artistic reasons prefer a light buff or cream. It is recognized that it is often worth while to sacrifice lighting economy for artistic effect.

A light colored room is much more cheerful than one finished in dark paint. In many cases dark surroundings have given the impression of bad lighting, while in reality there was a high enough intensity on the desks. The psychological effect of gloomy interiors is well known, and it is, of course, desirable to keep clerks and pupils buoyant and cheerful.

On the other hand, in the small room, too light colored side walls are likely to be too bright for ocular comfort. Some authorities set a reflection factor of 50 per cent as the maximum for side wall finishes, although the writer feels that one can go as high as 65 per cent without having discomfort.

Light surroundings, in general, reduce the conditions of glare. An artificial light source viewed against a bright ceiling is less annoying than in other positions. Light colored walls diffuse the light back toward the side of the room with windows, which lessens the contrast between the bright sky and adjacent walls.

As has been pointed out before, glossy wall surfaces should not be used, and even the furniture and trim should not be highly varnished. In this connection, close co-operation between the builder and lighting engineer is essential.

Light buff window shades are desirable, and if these are drawn at night they materially assist in reflecting the light, rather than allowing it to escape to the street. If these shades are slightly

translucent they are very useful in the daytime in cutting down the direct sunlight, diffusing the light which passes through them, and preventing a sharp line of shadow demarcation which may result if opaque shades are used.

The *Code of Lighting School Buildings*, issued by the Illuminating Engineering Society, gives some interesting data on this subject as well as on the question of design of blackboards.

A pure white finish throughout is almost universally applicable to stores, not only for its effect on the amount of light utilized and general bright appearance desired, but for the color result secured.

White light striking a colored surface will have some of its rays absorbed and be reflected as colored rather than white light. (This property is what makes the surface colored.) Hence, if an approximation to daylight is used as a light source, and all of the reflected light tinted, the final effect will be of a different color from that given out by the lamp. A practical illustration of this, showing a lack of understanding, is to be seen where MAZDA Daylight lamps are used in semi-indirect units in a room with a yellow ceiling. White surroundings do not modify the color of the reflected light as colored surroundings do.

(c) **Residences**

It is true that efficiency of light utilization is not at all important in the home, yet the color of walls and ceilings, particularly the former, has a remarkable bearing on the pleasing appearance of the room.

If these are of such colors that they do not reflect the light satisfactorily, no matter how much light is supplied, the room will never appear bright and cheerful. Dark green wall paper, for example, reflects very little light, and a room finished with this frequently is dull. A room finished in deep brown woodwork and sidewalls is often uncomfortable when lighted by ordinary methods of illumination. With general lighting systems, no matter how much precaution is taken to shield and diffuse the light, the lamp accessories show up in contrast to the dark background and become annoying bright spots. The only satisfactory method of lighting such an interior is by the use of table or floor lamps giving spots of fairly bright illumination around which the occupants are grouped and the attention concentrated, allowing the room as a whole to be comparatively dark or in shadow.

Light-colored wall paper and paint are, therefore, generally to be desired if the room is to be cheerful at night. An object or an interior looks cheerful and bright in proportion to the amount of

At the Edison Lighting Institute carefully designed equipment is used to demonstrate all forms of lighting. In one of the rooms, which is devoted to an exhibit of industrial lighting, the contrast between the levels of illumination present with light or dark colored wall surfaces is strikingly shown through the use of hinged panels painted white on one side and dark brown on the other.

light it reflects back to the eye, although pure white finishes are not to be desired from an artistic standpoint. The study of the psychological effect of the different colors is most interesting, but space does not permit a discussion of this phase of the subject.

Bibliography

Maintenance—

"Electrical Maintenance Methods in an Office Building," (Equitable Bldg., New York City), *Electrical World*, January 22, 1916.

"Costliness of Light Absorption," R. Kagerries *Electrical World*, May 26, 1917.

"Operation and Upkeep of Factory Lighting Systems," C. E. Clewell, *Electrical World*, August 11 and 18, 1917.

"Rating Artificial Lighting Systems," D. H. Tuck, *Electrical World*, October 20, 1917.

Bibliography (*continued*)

"Maintenance of Interior Lighting Systems," Ward Harrison and J. R. Colville, *Electrical World*, January 24, 1920.

"Maintenance of Indirect Lighting Equipment," J. L. Stair, *Trans. I.E.S.*, Vol. 15, page 292.

"Maintenance of Interior Lighting Systems," A. L. Powell, *Electrical Review*, February 11, 1920.

"Industrial Lighting Equipment and Its Maintenance," S. G. Hibben, *Safety Engineering*, January, 1921.

"Reduce Your Wastage of Light," Ward Harrison and J. R. Colville, *Electrical Review*, January, 1922.

"Design of Lighting Units Affects Maintenance," M. Luckiesh, *Electrical World*, November 25, 1922.

"Cleaning Lamps and Reflectors," N. T. Gordon, *Industrial Engineering*, January, 1923.

"Depreciation of Lighting Equipment Due to Dust and Dirt," E. A. Anderson and J. M. Ketch, *Trans. I.E S.*, Vol. 19, page 55.

Painting—

"Reflection from Painted Surfaces," Louis Bell, *Electrical World*, January 22, 1915.

"Air Shaft Illumination as Studied by Models," C. H. Sharp, *Trans. I.E.S.*, Vol. 9, page 598.

"Report of Committee on Glare-Diffusing Media Interior Furnishings," *Trans. I.E.S.*, Vol. 10, page 397.

"The Light Reflecting Values of White and Colored Paints," W. S. Gardner, *Journal Franklin Institute*, January, 1916.

"Effect of Interior Colors and Finishes Upon the Lighting of Rooms," S. G. Hibben, *Electric Journal*, July, 1916.

"Measurement of Reflection Factors," M. Luckiesh, *Electrical World*, May 19, 1917.

"Effect of Wall Colors on Lighting Requirements," *Electrical World*, August 16, 1919.

"Effect of Color of Walls and Ceilings on Resultant Illumination," A. L. Powell, *G-E Review*, March, 1920.

"Lighting Efficiency Decreased Twenty Per Cent by Pulleys and Columns," *Electrical World*, October 23, 1920.

"A Paint That Will Not Reflect Ultra Violet Rays," W. S. Andrews, *G-E Review*, October, 1921.

"Paints for Integrating Spheres," A. H. Taylor, *Trans. I.E.S.*, Vol. 16, page 587.

"Proper Painting as an Aid to Interior Illumination," Walter Sturrock, *Safety Engineering*, August, 1924.

"Reflection Factors of Industrial Paints and Pigments," H. A. Gardner, *Trans. I.E.S.*, Vol. 17, page 318.

"Determination of Reflection Factor of Surfaces," W. F. Little, *Trans. I.E.S.*, Vol. 18, page 333.

"Influence of Paint on Interior Illumination," R. L. Hallett, *Trans. I.E.S.*, Vol. 18, page 338.

"Paint Characteristics and Conditions to be Considered in Effecting Better Illumination," C. H. Bryce, *Trans. I.E.S.*, Vol. 18, page 347.

"Paint as an Aid to Illumination from the Machinery Painting Angle," L. E. Jamme, *Trans. I.E.S.*, Vol. 18, page 355.

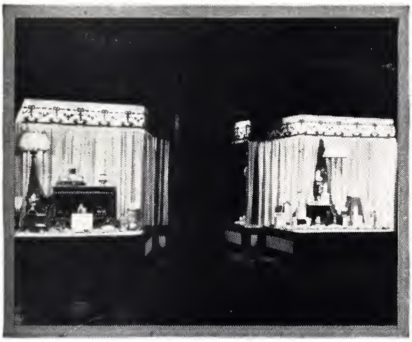
"Emissive Tests of Paints for Decreasing or Increasing Heat Radiation from Surfaces," W. W. Coblentz and C. W. Hughes, *Bureau of Standards Tech. Paper*, No. 254.

"The Reflecting Properties of White Interior Paints of Varying Compositions," A. L. Powell and R. B. Kellogg, *Trans. I.E.S.*, Vol. 21, page 70.

"Lighting Value of Paint in Industrial Plants," M. Luckiesh and E.W. Commery, *Industrial Engineering*, August, 1926, page 350.

"The Lighting Value of Paint," *Electrical World*, August 27, 1927, page 397.

Auditorium, Showing Miniature Stage and Specially Designed Lighting Units



Model Show Windows

Living Room of the Model Apartment

Street Lighting Exhibit

Individuals or groups are always welcome. The Institute is open from nine to five every weekday except Saturday. Special arrangements may be made for groups at night. Further details regarding the Institute may be obtained and arrangements for visits made by writing the Edison Lighting Institute, Edison Lamp Works of the General Electric Co., Harrison, N. J., or by telephoning Harrison 8000, extension 380.

Visit the Edison
Lighting Institute
"20 minutes from Broadway"